MP-669
JUNE 1963

# Soils OF THE SOUTHWESTERN GREAT PLAINS FIELD STATION


A profile of Pullman silty clay loam See description of a similar profile from the station, page 6.

TEXAS A&M UNIVERSITY
TEXAS AGRICULTURAL EXPERIMENT STATION
R. E. PATTERSON, DIRECTOR, COLLEGE STATION, TEXAS
*In Cooperation with the U. S. Department of Agriculture*

# *summary*

Pullman silty clay loam is the major soil type on the Southwestern Great Plains Field Station. Smaller areas of Randall clay, Mansker clay loam and Roscoe clay are also present. An insignificant area of dark variants of Church and Roscoe soils also occur. Soils on the field station represent about 12 million acres on the Southern High Plains of Texas, New Mexico and Oklahoma. The major soils of the region are of the Reddish Chestnut, Calcisol and Grumusol great soil groups; they are reddish brown to grayish brown or dark gray wth surface textures ranging from clay to loam. In Pullman soils, a horizon of calcium carbonate accumulation occurs from 24 to 72 inches beneath the soil surface.

Soils on the field station are representative of the Pullman series, one of the most extensive and important soil series on the High Plains of Texas. Soil management difficulties in the area result from the inherently low water intake rates and the erratic climate.

Efficient management of Pullman soils should be designed to counteract the adverse effects of low rainfall, high winds, moderately erodible soils and low water intake rates. During periods of low rainfall, wind erosion can become critical on Pullman and associated soils and is best controlled by stubble-mulch tillage for surface residue management.

The purpose of research at the Southwestern Great Plains Field Station is to develop soil, crop and livestock management practices that will permit dryland and irrigation farmers to use soil and climatic resources for an efficient and stable agriculture.

# *contents*

# Soils OF THE SOUTHWESTERN GREAT PLAINS FIELD STATION

HOWARD M. TAYLOR, C. E. VAN DOREN, CURTIS L. GODFREY and JAMES R. COOVER*

*The Southwestern Great Plains Field Station is the main research center in soils and crops for the "hardlands" part of the High Plains of Texas, New Mexico and Oklahoma. These predominantly fine-textured soils occupy about 12 million acres in an area bounded by Perryton, Crosbyton and Vega, Texas; Clovis and Tucumcari, New Mexico; and Guymon, Oklahoma. About 9,500,000 acres of the hardlands are located in Texas. Pullman soils, the major soil series on the experiment station, are estimated to exceed 5 million acres.*[1]

The experiment station is located at Bushland, Texas, near the center of the hardlands in Potter and Randall counties, 14 miles west of Amarillo, Texas, on Interstate Highway 40. Elevation of the headquarters is 3825 feet above mean sea level, Figure 1. The 1,616-acre site has almost level to gently sloping topography, except near the edge of the playa, or intermittent lake, southwest of the field station headquarters.

Site for the experiment station was purchased by the Federal Government in July 1936. Cooperative experimental studies were started on the Amarillo Experiment Station in the spring of 1938 by the Research Division, Soil Conservation Service, U. S. Department of Agriculture, and the Texas Agricultural Experiment Station. Early research work involved stubble-mulch tillage, wheat breeding, moisture conservation, wind erosion control, grass reseeding, livestock management, insect control and weed control.

In 1953, federal responsibilities at the experiment station were transferred from the Soil Conservation Service to the Bureau of Plant Industry, Soils and Agricultural Engineering, USDA. In 1954, the federal research program was transferred to the Agricultural Research Service, USDA. On December 20, 1956, the name "Amarillo Experiment Station" was changed to "Southwestern Great Plains Field Station."

Research investigations are conducted in livestock management, soil fertility under irrigated and dry farming conditions, soil structure and soil compaction, moisture conservation, surface runoff and water erosion control, insect and weed control, crop rotations, crop breeding, grass seeding machinery and practices, irrigation water management, groundwater recharge and wind erosion control.

## Climate

Soil management practices and crop production on the Southern Great Plains are critically related to climatic and weather conditions. For this reason, the climate of the area is discussed in considerable detail as background for better evaluation of the subsequent soils information.

Weather records have been maintained at the field station since 1939, but records have been maintained at Amarillo since 1892. Distance between the two weather stations is about 20 miles. Climatic trends at the two locations are similar, but the mean annual rainfall is slightly higher at Amarillo than at Bushland.

Mean annual rainfall at the Southwestern Great Plains Field Station for a 23-year period, 1939-1961, was 18.70 inches (Figure 2). The lowest annual rainfall during the 23 years was 12.13 inches in 1940; the highest was 32.56 inches in 1941. The variability in annual rainfall is indicated by the fact that the extremes occurred in two consecutive years. In addition, annual rainfall within 2 inches of the long-time average occurred during only 6 of the 23 years of record. Annual rainfall of less than 15 inches occurred in 7 of the 23 years. Thirteen years were be-

*Respectively, research soil scientist, Soil and Water Conservation Research Division, U. S. Department of Agriculture; superintendent, USDA and Texas Agricultural Experiment Station, Bushland, Texas; associate professor, Department of Soil and Crop Sciences, College Station, Texas; and state soil scientist, Soil Conservation Service, USDA, Temple, Texas.

[1]Unpublished manuscript "Summary of Soils of Texas" by Harvey Oakes, Soil Conservation Service, USDA.

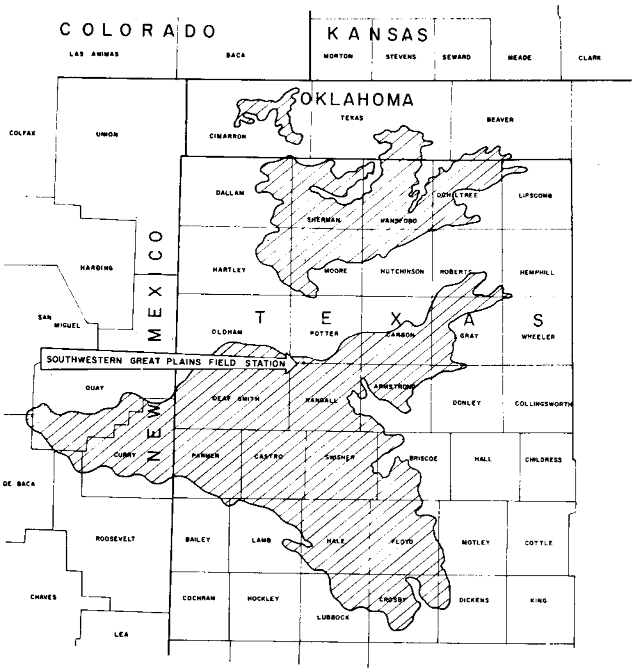


**Figure 1. Location of the Southwestern Great Plains Field Station and main area represented by the soils of the station.**

low average in annual rainfall and 10 years were above average.

Drouths are common in the area served by the Southwestern Great Plains Field Station. Prolonged drouths have occurred several times during the period in which weather records have been maintained at Amarillo. The famous drouth of the 1930's that led to the "dust bowl" was neither the longest nor the driest. For the 5-year drouth of 1952-56 average rainfall at Bushland was 14.44 inches and at Amarillo, 12.55 inches. Average rainfall during the drouth of 1933-37 was 15.59 inches at Amarillo. Weather records were not maintained at Bushland during the drouth of the 1930's.

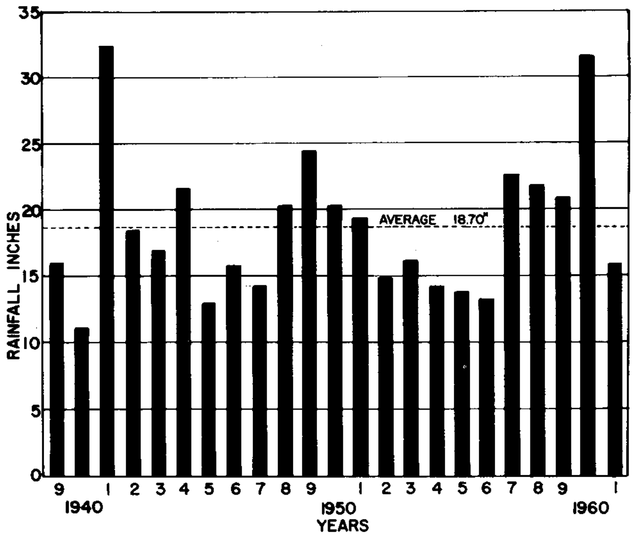


**Figure 2. Annual rainfall at the Southwestern Great Plains Field Station.**

Average monthly rainfall and evaporation are shown in Figure 3. The rainfall data, presented on a monthly basis, show peaks in May and July. Drouths are common during the summer. For example, average July rainfall is 2.88 inches, but less than half of this occurred in 8 of the 23 years. The maximum average rainfall, 3.2 inches, occurs during a 30-day period between May 10 and June 10. After June 10, the average rainfall for each 10-day period fluctuates, but the average amounts of rainfall gradually decrease to a low of 0.12 inch of precipitation during the 10-day period from February 10 to 20. Unlike some other locations on the High Plains, there is no second sharp peak in rainfall during late summer or fall.[2]

Evaporation records have been maintained at the experiment station since 1940. From 1940 to 1950, these records were maintained only from April 1 to October 1. Since January 1, 1951, records have been maintained throughout the year. Mean annual evaporation from a free water surface in a Young screen pan is about 81.90 inches.[3] Evaporation was 58.28 inches in 1960, a year with above-normal summer rainfall, and 99.25 inches in 1956, a dry year.

Mean annual relative humidity at the station is 51.4 percent. The mean was 36.5 percent in 1952, while it was 66.2 percent in 1944. The all-time monthly mean low relative humidity was 20.8 percent during the dry month of June 1953. The all-time high monthly mean was 87.8 percent in February 1948.

Mean annual temperature at the Southwestern Great Plains Field Station during the 23-year period is 57.5° F. with a maximum daily average of 72.6° F. and a minimum daily average of 42.4° F. A wide range in temperature is common. When a polar front arrives during the winter, the temperature may drop 40 or 50 degrees in a few hours. A record high of 109° F., occurred in June 1953. Temperatures of 100° F. or above occur on an average of 5 days per year. The record low temperature of —15° F. was recorded in January 1959. Minimum daily temperature will be 32° F. or less for approximately 120 days each year. Average monthly maximum and minimum temperatures are shown in Figure 4.

Wind movement is higher at the Southwestern Great Plains Field Station and throughout the High Plains in general than in areas further east and southeast. The 23-year average wind movement, measured 20 inches above the ground at the station, is 6.8 miles

[2]Hildreth, R. J., and Thomas, G. W. Farming and Ranching Risk as Influenced by Rainfall. 1. High and Rolling Plains of Texas. MP-154, Texas Agr. Expt. Sta., College Station, Texas, January 1956.

[3]Bloodgood, D. W., Patterson, R. E., and Smith R. L., Jr. Water Evaporation Studies in Texas, Texas Agr. Expt. Sta., College Station, Texas, Nov. 1954.

per hour. However, the long-term average wind velocity does not represent adequately wind conditions at Bushland. Windstorms with sustained velocities greater than 30 miles per hour are frequent during February, March and April. August has the least wind movement. During dry years, or when insufficient protection is provided, soil erosion by wind can be serious. In addition to this soil erosion, the high winds increase evaporation of water from the soil and transpiration from growing crops.

Average growing season at the station is about 193 days.[4] The longest recorded frost-free period was 224 days in 1943; the shortest was 165 days in 1954. The first killing frost occurs about October 28, but killing frosts have occurred as early as October 7 in 1952 and as late as November 10 in 1942 and 1944. The last killing frost in the spring usually is about April 18, but in 1943 the last killing frost in spring was as early as March 22. The latest killing frost on record occurred May 14, 1953.

Climate at the station is typical of much of the hardlands portion of the High Plains of Texas and adjoining states. The northern and northwestern portions of the area are slightly cooler in winter. Average annual rainfall is somewhat lower in the western portion. As an example, the annual rainfall averages about 1 inch per year less at Vega, than at Amarillo, 35 miles to the east.

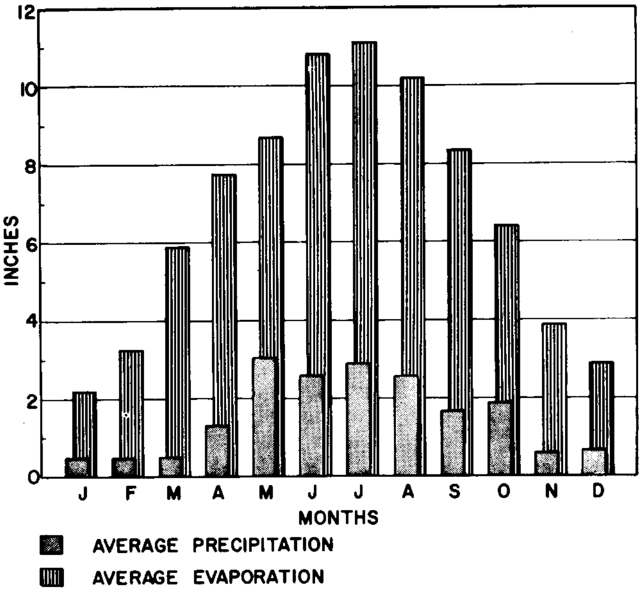


**Figure 3. Average monthly rainfall and evaporation at the Southwestern Great Plains Field Station.**

## *Soils*

Pullman silty clay loam is the major soil type on the experiment station (Figure 5 and Table 3). There are smaller areas of Randall clay, Roscoe clay, Church clay and Mansker clay loam. These latter soils are associated with the basin of an intermittent lake (playa) southwest of the station headquarters.

The Pullman soils are classified in the Reddish Chestnut great soil group (Subgroup "Albic Argustoll" in 7th Approximation) and have developed in a relatively cool, semiarid climate from medium to fine-textured calcareous sediments largely or wholly of eolian origin. They occupy extensive almost level, smooth areas interrupted by playas or basins containing other soils. Typical native vegetation is shortgrass, principally blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*). Wheat and grain sorghum are the major cultivated crops on most of the Pullman soils, but some cotton is grown toward the southern extent of the series.

The surface layer of typical Pullman soils is brown to dark brown silty clay loam, but texture may range from clay loam to loam. The surface layer usually is 4 to 7 inches thick, changing rather abruptly to a dark brown to dark grayish-brown clay with distinctly blocky structure. Buried horizons of older soils often occur at 3 to 5 feet below the soil surface. These buried horizons usually are clay loam in texture. Depth to the caliche layer (IIC1ca horizons, principally $CaCO_3$) on the experiment station ranges from 5 to 6 feet on 0 to 1 percent slopes and 2 to 4 feet on slopes of 1 to 3 percent.

During 1957, a representative Pullman silty clay loam profile, as it occurs on the experiment station, was described and sampled by soil horizons and subhorizons. Unless otherwise noted, all analyses of Pullman soils presented in this bulletin were obtained from soil of this pit.

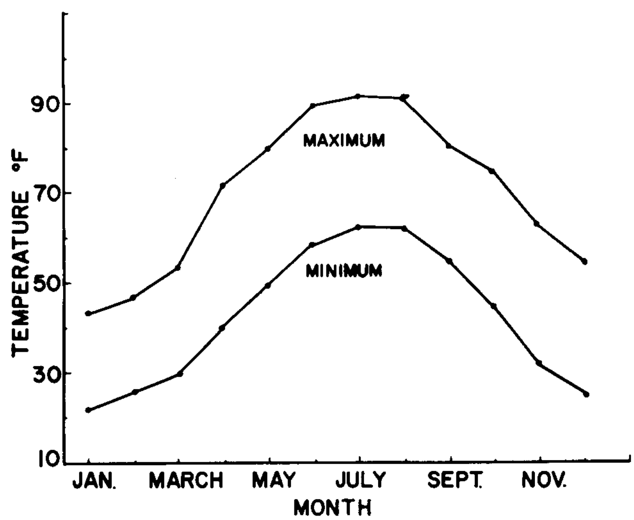


**Figure 4. Average monthly maximum and minimum temperatures at the Southwestern Great Plains Field Station.**

[4]"Killing frosts" and "growing seasons" are based on records at the experiment station and generally refer to temperatures of approximately 32° F. and the longest continuous warm growing season between 32° F. temperatures, respectively.

## PULLMAN SILTY CLAY LOAM (CULTIVATED)

*Location*: Approximately 150 feet north of county road and 500 feet east of SW corner of Section 197, Block 9, BS&F Survey, Randall county, Texas.

Ap

0-5 inches, dark grayish-brown (10YR 4/2) silty clay loam; very dark grayish brown (10YR 3/2) when moist; weak granular structure; friable when moist; noncalcareous; abrupt boundary.

B21t

5-9 inches, dark grayish-brown (10YR 4/2) light clay; very dark grayish brown (10YR 3/2) when moist; moderate fine blocky and some subangular blocky structure; very hard when dry; sticky and plastic when wet; continuous thin clay films; few very fine pores; noncalcareous; clear boundary.

B22t

9-18 inches, dark brown (7.5YR 4/2) clay; dark brown (7.5YR 3/2) when moist; moderate to strong medium blocky structure; peds have more distinct horizontal cleavage than vertical; continuous thin clay films; extremely hard when dry; sticky and plastic when wet; few very fine pores; noncalcareous; clear boundary.

B31ca

18-28 inches, brown (7.5YR 4/3) clay; dark brown (7.5YR 3/3) when moist; structure, consistence, clay films, and porosity similar to above; few soft masses of $CaCO_3$ mostly between peds; strongly calcareous; gradual boundary.

IIB32

28-38 inches, reddish-brown (5YR 5/3) clay loam; dark reddish brown (5YR 3/2) when moist; weak medium blocky structure; ped surfaces somewhat knobby; continuous thin clay films; very hard when dry; firm when moist; few fine pores; few films and threads of $CaCO_3$, films mostly on ped surfaces; weakly calcareous; gradual boundary.

IIB33

38-53 inches, reddish-brown (5YR 5/4) clay loam; reddish brown (5YR 4/4) when moist; structure, consistence, porosity and clay films similar to above; few films and threads of $CaCO_3$ mostly on ped surfaces; soil mass generally noncalcareous; few black films apparently of manganese oxide on larger ped surfaces; occasional krotovina about 4 inches in diameter, one contains pellets of silty clay material about ½ inch in diameter.

IIC1ca

53-65 inches, reddish-yellow (5YR 6/6) clay loam; yellowish red (5YR 5/6) when moist; friable when moist; many soft masses of $CaCO_3$; very strongly calcareous.

*Range in Characteristics:* The A horizon is typically 6 inches thick, but ranging from 5 to 8 inches. The color when dry is dark grayish brown (10YR 4/2) to dark brown (7.5YR 4/2), or brown. The B21t horizon is weak blocky to moderate fine or medium blocky in structure, and the B22t is moderate medium to strong medium block. This soil in the lower area south of the large playa is less red in the upper horizons with dark grayish-brown colors in the B21t, B22t and B31ca, but is underlain by the typical brown and reddish-brown buried horizons. The slope gradient is typically about 0.3 percent and ranges from practically level to 3 percent.

Mechanical analyses of a typical profile of cultivated Pullman soil on the experiment station are given in Table 1. Textures of all horizons to 65 inches are clay loam or clay.[5] The zone of greatest clay concentration is in the 9 to 18-inch depth. Sand fractions were obtained from the 0 to 5-inch layer. Eighty-five percent of the total sand occurred in the very fine sand fraction and an additional 8 percent in the fine sand fraction.

Chemical data from the Pullman soil are presented in Table 2. Organic matter content of the surface horizon is 1.58 percent, whereas that from a nearby native grass site is 2.58 percent. The pH (hydrogen ion concentration) ranges from 6.3 in the surface horizon to 7.7 in the caliche layer. As indicated by the $CaCO_3$ equivalent, calcium carbonate is abundant only in the caliche layer. However, calcium is the principle exchangeable cation in all horizons. Free $Fe_2O_3$ is low in all horizons. Extractable sodium is about 10 percent of the cation exchange capacity in the 28 to 38 and 38 to 53-inch horizons.

Chemical analyses of the clay fraction extracted from a Pullman soil are presented in Table 4. Silica-sesquioxide ratios are relatively high. Cation exchange capacities of the less than 0.2-micron clay indicate that a montmorillonitic type clay mineral is present in all horizons. X-ray and differential thermal analyses also indicate that major quantities of montmorillonitic and illitic clays are present in all horizons of the profile. Minor quantities of kaolinitic clays usually occur in the 2 to 0.2-micron clay fraction.

Mineralogy of the very fine sand fraction of a Pullman soil is presented in Table 5. The zircon-tourmaline ratio often is used as an indicator of the uniformity of the soil parent material. There appear to be two distinct breaks within the Pullman profile. The zircon-tourmaline ratio changes from 1.28 in the

[5]This soil was correlated Pullman silty clay loam in the soil survey of the station.

23 to 33-inch layer to 3.14 in the 33 to 46-inch layer. Another shift in the ratio occurs when the 62 to 67-inch layer is compared with the 82 to 85-inch layer. The silica-sesquioxide ratio (Table 4) also indicates that the 80 to 85-inch layer is significantly different from the layer above it.

In 1960, bulk samples were collected by 1-foot increments to a depth of 40 feet at a location about 200 yards south of station headquarters. Mechanical analyses and carbonate distribution of the sediments underlying Pullman soil are presented in Figure 6. Considerable variation occurs both in size distribution of the silicate particles and in carbonate percentages. Carbonate content is relatively high in the 4 to 6-foot, 12 to 13-foot, 28 to 29-foot and 40-foot and deeper layers. Clay content in the silicate fraction is low in the 9 to 14-foot and the 34 to 37-foot layers. No silicate pebbles or stones were encountered above the 40-foot depth.

Water-retaining abilities of soils are extremely important both under dryland and irrigation farming conditions. Table 6 gives field capacity and permanent wilting percentage data for Pullman silty clay loam on the station. Field capacity values, as determined by field moisture sampling techniques, range from 20 to 26 percent moisture content by weight. Wilting point values range from 11 to 14 percent. The upper 6 feet of undisturbed Pullman silty clay loam soil can retain about 10.5 inches of available water. The 1/3 atmosphere soil moisture retention value commonly is used to approximate field capacity. However, experience of research workers at this station indicates that moisture retention curves which were obtained using disturbed samples should not be used to determine the moisture relations of undisturbed Pullman soils. For example, the 1/3 atmosphere value for the second foot of Pullman silty clay loam is about 34 to 35 percent moisture content by weight (Table 7). However, field capacity by field sampling is 24.5 percent moisture. When a soil horizon is pulverized by plowing, the soil moisture retention curves are useful to approximate field capacity. Differences in moisture retention at wilting point and at 15 atmosphere value are less than the differences at field capacity and 1/3 atmosphere value.

Table 8 gives plasticity data for Pullman silty clay loam soil on the station. These plasticity data often are useful in estimating engineering properties of soils. Pullman soils have moderate to high shrink-swell potential. Alternate wetting and drying cause moderate to severe building foundation problems on Pullman soil.

## ROSCOE CLAY

Roscoe clay (Subgroup "Typic Grumaquert" in 7th Approximation) is a dark gray Grumusol soil which occupies some of the gently sloping areas adjacent to the large playa on the experiment station. This moderately well-drained soil developed in calcareous dark gray or dark grayish-brown, fine-textured sediments. A slight gilgai microrelief is characteristic of the physiography. This soil exhibits a moderate amount of cracking when dry. Predominant native grasses are blue grama, western wheatgrass and buffalograss. A small insignificant area of dark variants of Church and Roscoe soils also occurs on the station.

Some physical and chemical properties of the Roscoe clay at the experiment station are presented in Table 9. This soil is clay textured to 54 inches where texture changes to sandy clay loam. Soil pH is high at depths greater than 5 inches.

**TABLE 1. MECHANICAL ANALYSES OF A CULTIVATED PULLMAN SILTY CLAY LOAM[1]**

| Depth | Horizon | Sand | Silt | Clay | Textural class |
|---|---|---|---|---|---|
| Inches | | - - - | Percent | - - - | |
| 0- 5 | Ap | 39.2 | 31.6 | 29.2 | Clay loam[2] |
| 5- 9 | B21t | 31.6 | 29.6 | 38.8 | Clay loam |
| 9-18 | B22t | 23.5 | 32.7 | 43.8 | Clay |
| 18-28 | B31ca | 24.8 | 32.6 | 42.6 | Clay |
| 28-38 | IIB32 | 27.8 | 34.3 | 37.9 | Clay loam |
| 38-53 | IIB33 | 29.6 | 31.8 | 38.6 | Clay loam |
| 53-65 | IIC1ca | 41.9 | 21.2 | 36.9 | Clay loam[3] |

[1]Pipette method using hexametaphosphate as a dispersion agent.

[2]Sand fraction is high in very fine sand. This soil is difficult to distinguish in field mapping from extensive areas of Pullman silty clay loam in the High Plains. On this basis the Pullman soils on the station were correlated silty clay loam.

[3]Because of the destruction of significant amounts of $CaCO_3$ during the mechanical analysis procedure, the textural class of this horizon will not represent the actual field texture.

**TABLE 2. CHEMICAL DATA OF CULTIVATED PULLMAN SILTY CLAY LOAM[1]**

| | Extractable cations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Depth | Na[2] | K[2] | Ca[2] | Mg[3] | C.E.C.[4] | pH[5] | O.M.[6] | $CaCO_3$ Equiv.[7] | Free[8] $Fe_2O_3$ |
| Inches | - - - | Me/100 g. | - - - | | | | - - - | Percent | - - - |
| 0- 5 | .16 | 1.28 | 9.0 | 2.7 | 18.4 | 6.3 | 1.58 | .5 | .29 |
| 5- 9 | .33 | 1.15 | 13.7 | 3.5 | 19.6 | 6.3 | 1.29 | .4 | .22 |
| 9-18 | 1.21 | .94 | 40.0[9] | 3.2 | 20.0 | 7.5 | .94 | .5 | .30 |
| 18-28 | 1.66 | .92 | 40.0[9] | 3.7 | 23.9 | 7.6 | .69 | 3.5 | .25 |
| 28-38 | 1.96 | .80 | 37.5[9] | 3.7 | 20.9 | 7.7 | .63 | 3.5 | .19 |
| 38-53 | 1.87 | .74 | 33.0[9] | 3.7 | 17.4 | 7.6 | .22 | 2.7 | .21 |
| 53-58 | 1.66 | .31 | 44.0[9] | | | | .35 | 45.0 | .11 |
| 80-85 | 1.91 | .49 | 40.0[9] | 0.6 | 10.4 | 7.7 | .16 | 13.2 | .28 |

[1]Unpublished data of A. C. Mathers.

[2]Flame photometer used on ammonium acetate extract.

[3]Determined colormetrically by the thiazole yellow method.

[4]Sodium acetate method.

[5]Glass electrode.

[6]Wet combustion method.

[7]Calculated from weight loss upon addition of Hcl.

[8]Hydrosulfite-citrate method.

[9]Free carbonates present.

TABLE 3. SOILS OF THE SOUTHWESTERN GREAT PLAINS FIELD STATION, BUSHLAND, TE

| Map symbol | Soil name | Description of Soil: Surface soil | Subsoil | Substratum | Erosion hazard | Moisture and air relations | Fertil and produc |
|---|---|---|---|---|---|---|---|
| Pa | Pullman silty clay loam, 0-1% slopes | Grayish-brown to brown clay loam; granular and sub-angular blocky; friable moist; slightly hard dry; noncalcareous; 5 to 10 inches thick | Dark brown to brown clay; weak granular and coarse blocky; firm moist; very hard dry; calcareous; 20 to 30 inches thick | Brown to reddish-brown clay loam; moderate blocky and weak granular, becoming weakly prismatic with depth; calcareous (caliche occurs at 60 to 72 inches) | Slight to no water erosion hazard; slight wind erosion hazard | High capacity for available water; slowly permeable; aeration fair to poor when soil is at field capacity | Fertile anc productive moisture i quate. Wel for cropla |
| Pb | Pullman silty clay loam, 1-3% slopes | Same as above | Same as above | Same as above but depth to caliche 26 to 40 inches | Slight to moderate water erosion hazard; slight wind erosion hazard | High capacity for available water; slowly permeable; aeration fair to poor when soil is at field capacity | Fertile anc productive moisture i quate. Wel for cropla |
| Ra | Roscoe clay, 0-1% slopes | Dark grayish-brown clay; moderate medium granular becoming compound strong coarse and weak granular with increased depth; aggregates have glossy surfaces; extremely hard when dry; very firm when moist; noncalcareous 16 to 24 inches thick | Grayish-brown clay; strong medium blocky structure; extremely hard and very compact; mildly calcareous; 5 to 15 inches thick | Light brownish-gray or pale brown calcareous clay containing scattered soft concretions of lime carbonate. Very compact in upper part, becoming less compact and browner with depth; 30 to 60 inches thick | Slight to moderate water erosion hazard; slight wind erosion hazard | High capacity for available water; slowly permeable; aeration fair to poor when soil is at field capacity; receives runoff from surrounding areas | Fertile anc productive moisture quate. No suited for land in thi location. |
| Rb | Roscoe clay, 1-3% slopes | Same as above | Same as above | Same as above | Same as above | Same as above | Same as a |
| Rc | Randall clay (playa areas) | Gray heavy clay; weakly blocky to massive; very sticky and very stiff when wet; very hard when dry; noncalcareous; 10 to 30 inches thick | Gray heavy clay; slightly mottled with brown; very compact; very hard when dry; very slowly permeable; noncalcareous; 10 to 30 inches thick | Light gray clay mottled with pale yellow; soft black or brown concretions are common; neutral or calcareous | Receives deposition of soil by water; slight wind erosion hazard | High capacity for available water; very slowly permeable; soil often flooded | Not recom for cropla because of ing hazard |
| M | Mansker clay loam, 3-8% slopes | Dark grayish-brown clay loam; friable; strong medium granular structure; calcareous; 6 to 12 inches thick | Pale brown clay loam; friable; strong medium granular structure; strongly calcareous; contains some $CaCO_3$ concretions in lower part; 5 to 8 inches thick | Very pale brown strongly calcareous clay loam containing numerous soft to slightly indurated concretions of $CaCO_3$. Fewer concretions in lower depths; 15 to 50 inches thick. | High water erosion hazard; slight to moderate wind erosion | Low to moderate capacity for available water; moderately permeable | Low inher productivi suited for land. |
| C | Church and Roscoe soils, dark variant, 3-5% slopes | Dark grayish-brown clay; moderate fine to coarse blocky; sticky when wet, firm when moist, extremely hard when dry; weakly to strongly calcareous 10 to 20 inches thick | Dark grayish-brown to light brown clay; moderate to medium blocky to massive; sticky when wet; firm when moist, hard when dry; strongly calcareous; 15 to 25 inches thick | Gray to slight brown strongly calcareous clay; $CaCO_3$ concretions common; 15 inches or more thick | Slight to moderate water erosion hazard; slight to moderate wind erosion hazard | High to moderate capacity for available water; slow to moderately permeable | Moderatel tile and p tive when ture is ad Not suited cropland i location. |

| lity d tivity | Extent acreage on station | Percent of station | Representative of acreage in Texas High Plains (estimated) |
|---|---|---|---|
| d very e when is ade- ll suited nd. | 914 | 56.6 | 5,000,000 |
| d very e when is ade- ll suited nd. | 515 | 31.9 | 750,000 |
| d very e when is ade- t well crop- is | 21 | 1.3 | 50,000 |
| bove | 21 | 1.3 | 50,000 |
| mended nd f flood- d. | 115 | 7.1 | 500,000 |
| rent ty; not crop- | 17 | 1.0 | 200,000 |
| y fer- roduc- mois- equate. l for in this | 13 | 0.8 | 5,000 |
| | 1,616 | 100.0 | 6,555,000 |

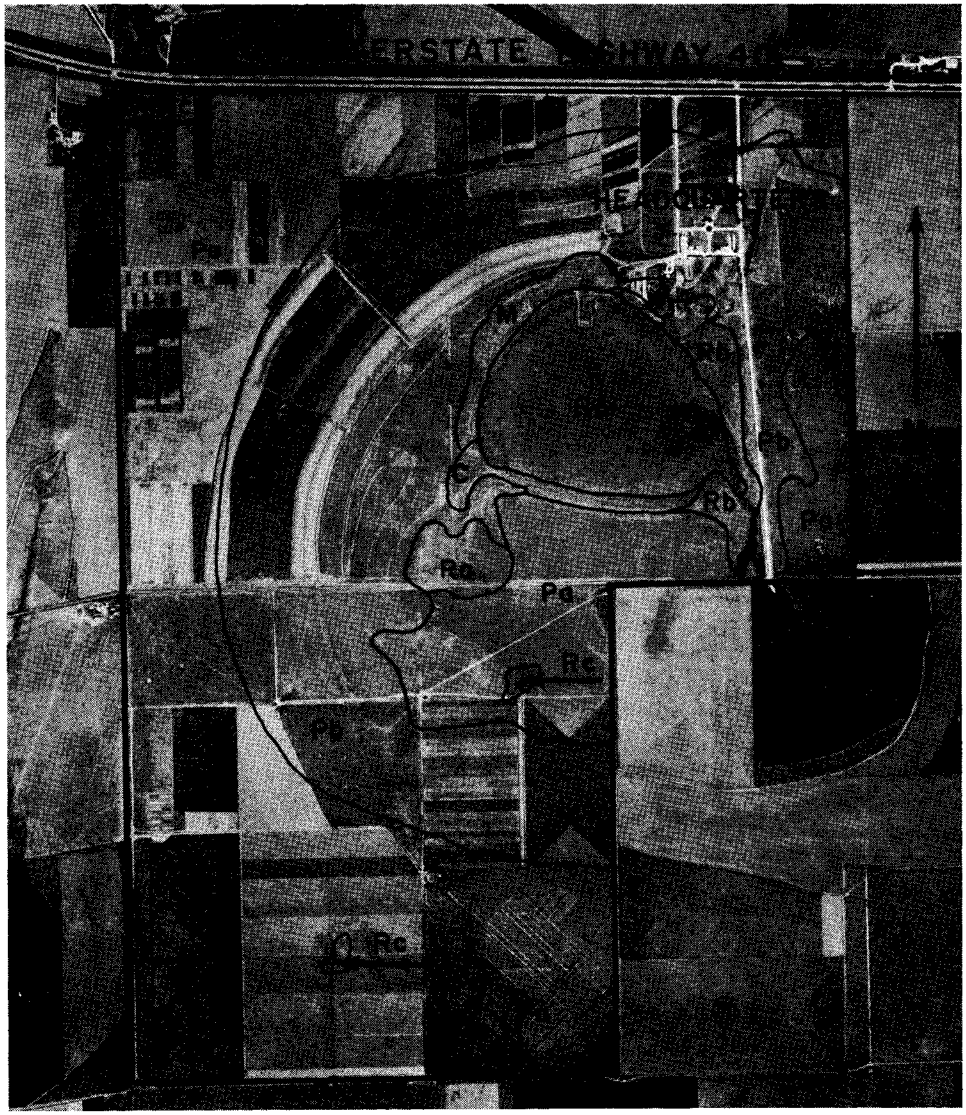


Figure 5. Soil map of Southwestern Great Plains Field Station, Bushland. Prepared by the Soil Conservation Service, U. S. Department of Agriculture and the Texas Agricultural Experiment Station.

**LEGEND**

**Soil Names**

**Symbols**

- **C** Church and Roscoe soils, dark variant, 3 to 5 percent slopes
- **M** Mansker clay loam 3 to 8 percent slopes
- **Pa** Pullman silty clay loam, 0 to 1 percent slopes
- **Pb** Pullman silty clay loam, 1 to 3 percent slopes
- **Ra** Roscoe clay, 0 to 1 percent slopes
- **Rb** Roscoe clay, 1 to 3 percent slopes
- **Rc** Randall clay

***Scale of map***

***1 inch = approximately 1,760 feet.***

***1,616 acres.***

EXAS

| ...lity ...d ...ctivity | Extent acreage on station | Percent of station | Representative of acreage in Texas High Plains (estimated) |
|---|---|---|---|
| d very e when is ade- ll suited nd. | 914 | 56.6 | 5,000,000 |
| d very e when is ade- ll suited and. | 515 | 31.9 | 750,000 |
| d very e when is ade- ot well crop- is | 21 | 1.3 | 50,000 |
| bove | 21 | 1.3 | 50,000 |
| mended nd f flood- d. | 115 | 7.1 | 500,000 |
| rent ty; not crop- | 17 | 1.0 | 200,000 |
| y fer- roduc- mois- equate. l for in this | 13 | 0.8 | 5,000 |
| | 1,616 | 100.0 | 6,555,000 |

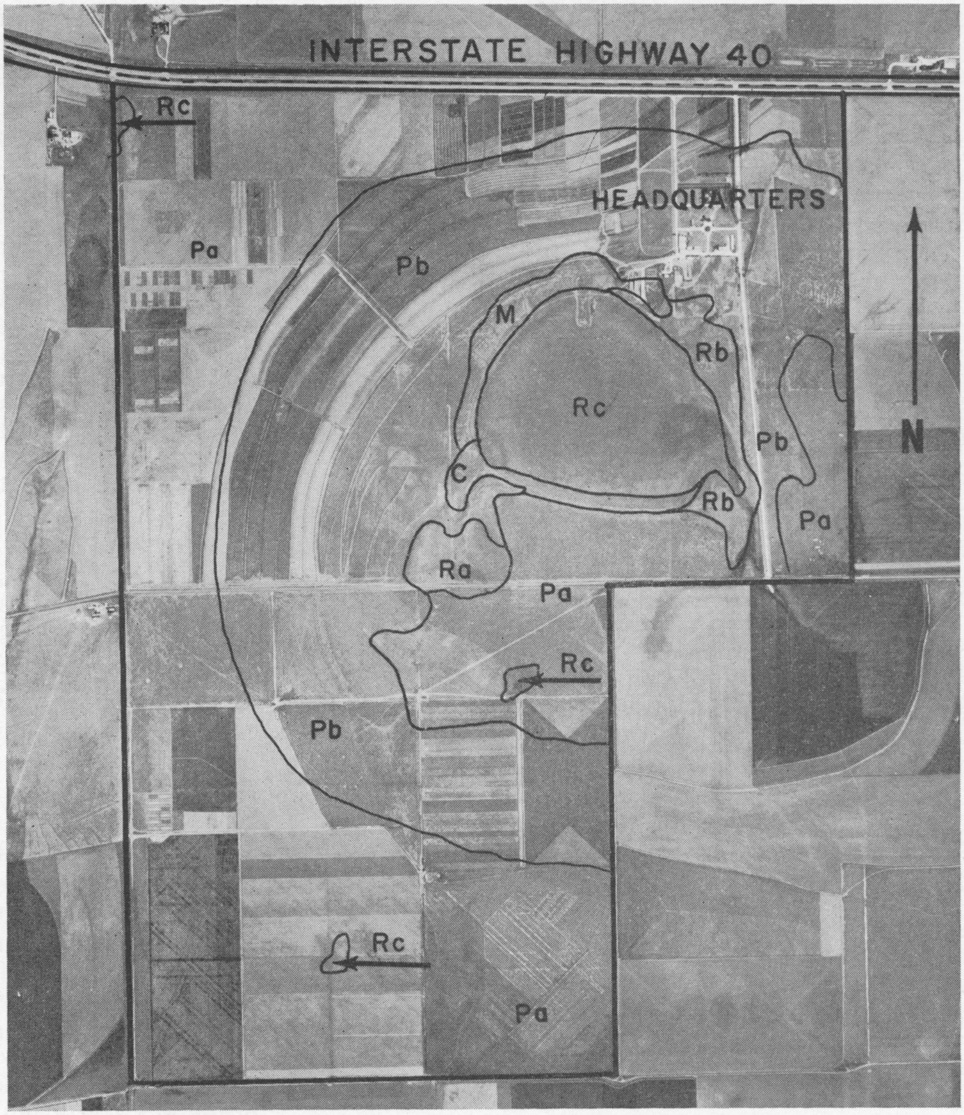


Figure 5. Soil map of Southwestern Great Plains Field Station, Bushland. Prepared by the Soil Conservation Service, U. S. Department of Agriculture and the Texas Agricultural Experiment Station.

LEGEND

Soil Names

Symbols
C Church and Roscoe soils, dark variant, 3 to 5 percent slopes
M Mansker clay loam 3 to 8 percent slopes
Pa Pullman silty clay loam, 0 to 1 percent slopes
Pb Pullman silty clay loam, 1 to 3 percent slopes
Ra Roscoe clay, 0 to 1 percent slopes
Rb Roscoe clay, 1 to 3 percent slopes
Rc Randall clay

*Scale of map*
*1 inch = approximately 1,760 feet.*
*1,616 acres.*

E SOUTHWESTERN GREAT PLAINS FIELD STATION, BUSHLAND, TEXAS

| il | Substratum | Erosion hazard | Moisture and air relations | Fertility and productivity | Extent acreage on station | Percent of station | Representative of acreage in Texas High Plains (estimated) |
|---|---|---|---|---|---|---|---|
| n r rd | Brown to reddish-brown clay loam; moderate blocky and weak granular, becoming weakly prismatic with depth; calcareous (caliche occurs at 60 to 72 inches) | Slight to no water erosion hazard; slight wind erosion hazard | High capacity for available water; slowly permeable; aeration fair to poor when soil is at field capacity | Fertile and very productive when moisture is adequate. Well suited for cropland. | 914 | 56.6 | 5,000,000 |
| | Same as above but depth to caliche 26 to 40 inches | Slight to moderate water erosion hazard; slight wind erosion hazard | High capacity for available water; slowly permeable; aeration fair to poor when soil is at field capacity | Fertile and very productive when moisture is adequate. Well suited for cropland. | 515 | 31.9 | 750,000 |
| ky | Light brownish-gray or pale brown calcareous clay containing scattered soft concretions of lime carbonate. Very compact in upper part, becoming less compact and browner with depth; 30 to 60 inches thick | Slight to moderate water erosion hazard; slight wind erosion hazard | High capacity for available water; slowly permeable; aeration fair to poor when soil is at field capacity; receives runoff from surrounding areas | Fertile and very productive when moisture is adequate. Not well suited for cropland in this location. | 21 | 1.3 | 50,000 |
| | Same as above | Same as above | Same as above | Same as above | 21 | 1.3 | 50,000 |
| n ct; ; le; o | Light gray clay mottled with pale yellow; soft black or brown concretions are common; neutral or calcareous | Receives deposition of soil by water; slight wind erosion hazard | High capacity for available water; very slowly permeable; soil often flooded | Not recommended for cropland because of flooding hazard. | 115 | 7.1 | 500,000 |
| am; um ₃ ick | Very pale brown strongly calcareous clay loam containing numerous soft to slightly indurated concretions of $CaCO_3$. Fewer concretions in lower depths; 15 to 50 inches thick. | High water erosion hazard; slight to moderate wind erosion | Low to moderate capacity for available water; moderately permeable | Low inherent productivity; not suited for cropland. | 17 | 1.0 | 200,000 |
| to od- cky hen t, ng- | Gray to slight brown strongly calcareous clay; $CaCO_3$ concretions common; 15 inches or more thick | Slight to moderate water erosion hazard; slight to moderate wind erosion hazard | High to moderate capacity for available water; slow to moderately permeable | Moderately fertile and productive when moisture is adequate. Not suited for cropland in this location. | 13 | 0.8 | 5,000 |
| | | | | | 1,616 | 100.0 | 6,555,000 |

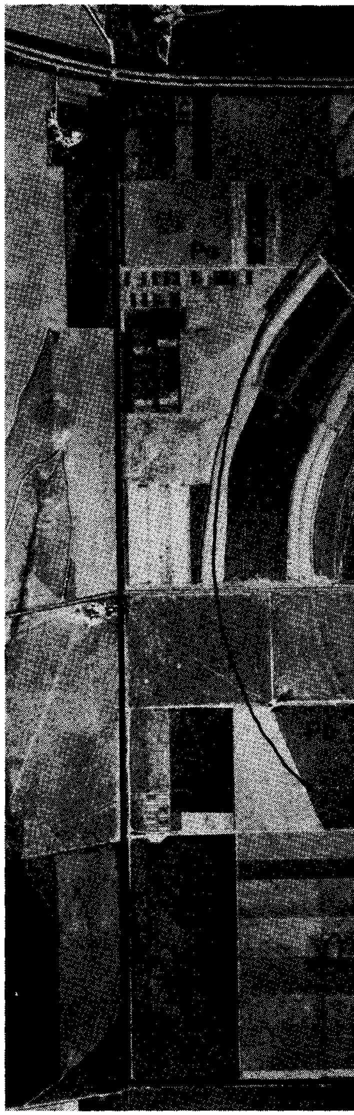

Figure 5. Soil map of Southwester
Soil Conservation Service, U. S. D
periment Station.

Symbols
C Church and Ro
M Mansker clay l
Pa Pullman silty
Pb Pullman silty c
Ra Roscoe clay, 0
Rb Roscoe clay, 1
Rc Randall clay
*Scale of map*
*1 inch = approxima*
*1,616 acres.*

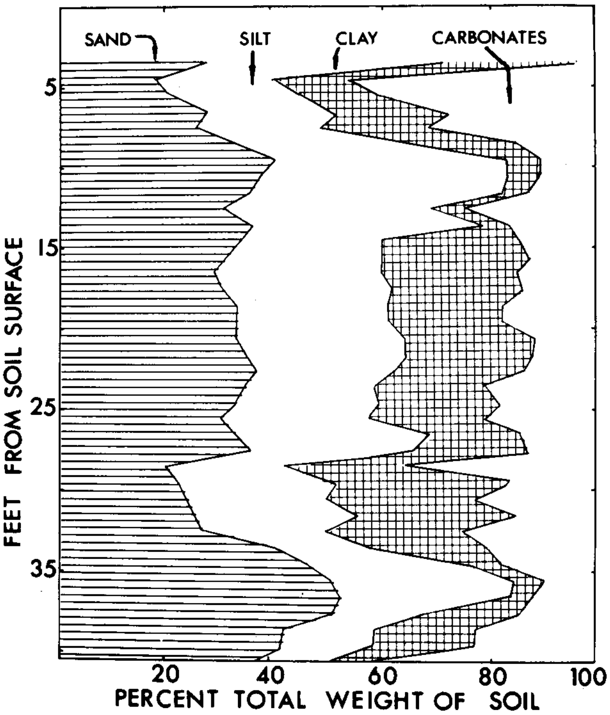


Figure 6. Carbonate percentage and silicate particle size distribution to a 40-foot depth near the headquarters, Southwestern Great Plains Field Station, Bushland.

## MANSKER CLAY

Mansker clay loam (Subgroup "Typic Calcustoll" in 7th Approximation) is a grayish-brown Calcisol developed in the Reddish Chestnut and Reddish Brown soil zones from strongly calcareous medium to fine-textured sediments. Mansker soils occur on sloping areas near the large playa on the experiment station. Native vegetation chiefly is grama grasses with a few shrubs. The Mansker soils are very susceptible to wind erosion when cultivated, because the fine granules induced by the abundance of $CaCO_3$ are shifted readily by wind action.

Data for Mansker clay loam are presented in Table 10. The soil pH is high throughout the calcareous profile. Clay contents below the 1-inch level range from 34 to 44 percent. Organic matter contents of the Mansker loam are higher than those in Roscoe clay.

TABLE 4. CHEMICAL ANALYSES OF THE CLAY FRACTION FROM PULLMAN SILTY CLAY LOAM[1]

| Depth | C.E.C.[2] | $SiO_2$[3] | $Al_2O_3$[4] | $Fe_2O_3$[5] | CaO[6] | Loss on[7] ignition | $SiO_2/R_2O_3$ |
|---|---|---|---|---|---|---|---|
| Inches | Me/ 100 g. | | | Percent | | | |
| 0- 5 | 73.3 | 46.1 | 13.5 | 7.0 | 6.3 | 14.7 | 4.37 |
| 5- 9 | 86.0 | 41.6 | 14.3 | 6.9 | 6.0 | 13.4 | 3.78 |
| 9-18 | 83.2 | 43.7 | 17.9 | 6.7 | 9.1 | 11.9 | 3.36 |
| 18-28 | 83.5 | 39.2 | 15.0 | 4.0 | 8.9 | 9.9 | 3.80 |
| 28-38 | 79.5 | 39.2 | 22.6 | 6.3 | 10.5 | 9.8 | 2.52 |
| 38-53 | 83.8 | 40.8 | 16.9 | 8.8 | 10.8 | 9.5 | 3.10 |
| 53-58 | 93.4 | 16.6 | 7.2 | 3.1 | 34.3 | 23.0 | 3.08 |
| 80-85 | 92.0 | 31.2 | 22.4 | 7.3 | 20.2 | 12.4 | 1.97 |

[1]Unpublished data of A. C. Mathers.
[2]Na acetate method on $\angle 0.2$ m clay.
[3]Molybdenum yellow on sodium carbonate fusate.
[4]Aluminon method using thioglycollic acid to complex iron.
[5]o-phenanthroline method.
[6]Permanganate titration method.
[7]Heated to 1000° C. in a muffle furnace.

TABLE 5. MINERALOGY OF THE VERY FINE SAND FRACTION OF PULLMAN SILTY CLAY LOAM[1]

| Minerals (percent)[2] | Depth, inches 0-8 | 8-23 | 23-33 | 33-46 | 46-62 | 62-67 | 82-85 |
|---|---|---|---|---|---|---|---|
| Heavy suite (sp. gr. >2.95) | | | | | | | |
| Opaque | 49.5 | 47.7 | 52.9 | 54.6 | 50.1 | 45.9 | 45.6 |
| Garnet | 2.1 | 1.9 | 4.1 | 2.6 | 2.4 | 2.6 | 3.8 |
| Epidote[3] | 17.3 | 15.7 | 16.2 | 15.6 | 17.2 | 10.3 | 12.2 |
| Amphibole | 6.6 | 13.0 | 7.4 | 7.2 | 8.7 | 15.5 | 12.7 |
| Pyroxene | 3.5 | 1.7 | 1.9 | 0.5 | 0.7 | 3.3 | 5.2 |
| Others | 5.4 | 4.8 | 4.3 | 4.6 | 4.7 | 5.7 | 5.2 |
| Zircon | 7.1 | 8.0 | 7.4 | 11.3 | 12.0 | 11.2 | 8.5 |
| Tourmaline | 8.5 | 7.2 | 5.8 | 3.6 | 4.2 | 5.5 | 6.8 |
| Zircon/ tourmaline | 0.84 | 1.10 | 1.28 | 3.14 | 2.84 | 2.04 | 1.24 |
| Light suite (sp. gr. <2.95) | | | | | | | |
| Quartz | 81.1 | 76.8 | 77.0 | 84.5 | 82.5 | 80.2 | 84.3 |
| Orthoclase | 13.6 | 18.3 | 16.1 | 14.0 | 14.7 | 15.1 | 9.7 |
| Microcline | 3.0 | 2.7 | 4.1 | 1.5 | 0.7 | 2.0 | 1.6 |
| Others | 2.3 | 2.2 | 2.8 | 0.0 | 2.1 | 2.7 | 4.4 |

[1]Unpublished data of F. B. Lotspeich. Samples were collected from native pasture site 200 feet south of the described profile.
[2]Calculated as percent of the total heavy or light mineral suite.
[3]Includes zoisite.

## RANDALL CLAY

Randall clay (Subgroup "Entic Grumaquert" in 7th Approximation) occupies the floor of the enclosed depression or intermittent lake on the experiment

TABLE 6. AVAILABLE MOISTURE DATA FOR PULLMAN SILTY CLAY LOAM[1]

| Depth | Field capacity[2] | Permanent wilting percentage | Available water |
|---|---|---|---|
| Feet | Percent | | Inches |
| 0-1 | 26.0 | 11.7 | 2.3 |
| 1-2 | 24.5 | 13.5 | 2.0 |
| 2-3 | 22.5 | 12.5 | 1.9 |
| 3-4 | 20.5 | 13.0 | 1.5 |
| 4-5 | 20.0 | 12.0 | 1.4 |
| 5-6 | 20.0 | 12.0 | 1.4 |

[1]Unpublished data of M. E. Jensen and W. H. Sletten.
[2]Data obtained by field sampling techniques.

TABLE 7. SOIL MOISTURE RETENTION AND BULK DENSITY DATA FOR CULTIVATED PULLMAN SILTY CLAY LOAM

| Soil depth | Atmospheres soil moisture tension 1/3[1] | 1[1] | 5[2] | 15[2] | Bulk density[3] |
|---|---|---|---|---|---|
| Inches | — — — — — Percent — by weight | | | | G/cm[3] |
| 0- 5 | 28.3 | 19.2 | 13.8 | 11.1 | 1.39 |
| 5- 9 | 32.0 | 24.0 | 18.9 | 15.4 | 1.50 |
| 9-18 | 34.9 | 26.7 | 21.8 | 17.1 | 1.50 |
| 18-28 | 34.0 | 26.2 | 21.3 | 16.4 | 1.50 |
| 28-38 | 32.5 | 24.4 | 21.0 | 15.1 | 1.58 |
| 38-53 | 32.5 | 25.0 | 19.8 | 15.8 | 1.59 |
| 53-58 | 30.0 | 24.6 | 21.9 | 11.3 | 1.67 |
| 58-76 | 29.8 | | | | |
| 80-85 | 28.9 | 23.1 | 17.4 | 12.6 | |

[1]Pressure plate technique.
[2]Pressure membrane technique.
[3]Soil core with Pomona Sampler.

station and occurs in similar positions throughout the High Plains. Randall soils are gray clayey intrazonal soils (Grumusols) found in the Chestnut and Reddish Brown soil zones of the Southern Great Plains. They have developed on clays and silts of the High Plains sediments that have been modified by poor drainage. Randall clay soils remain under water for extended periods following rainy seasons. Because of flooding and undesirable physical properties, most Randall soils are unsuited for cultivation. However, some of the Randall soils located in shallow playas are cultivated. In deeper lakes, some Randall soils may be cultivated if special provision is made to intercept the runoff water usually flooding these soils during rainy seasons.

Zita, Potter and Portales soils occupy significant acreages in the fine-textured portion of the High Plains area, but they do not occur on the experiment station. These latter soils generally are more calcareous in the upper horizons than are Pullman soils.

TABLE 8. ATTERBERG LIMITS FOR PULLMAN SILTY CLAY LOAM

| Horizon | Liquid limit[1] | Plastic limit[1] | Plasticity index |
|---|---|---|---|
| Inches | — — Percent — — | | |
| 0- 5 | 30.5 | 20.4 | 10.1 |
| 5- 8 | 30.3 | 20.8 | 9.5 |
| 8-13 | 37.5 | 22.2 | 15.3 |
| 13-19 | 46.4 | 25.8 | 20.6 |
| 19-28 | 44.0 | 24.2 | 19.8 |
| 28-38 | 39.4 | 22.0 | 17.4 |
| 38-49 | 36.3 | 21.5 | 14.8 |
| 49-61 | 38.3 | 21.4 | 16.9 |
| 61-76 | 33.0 | 20.2 | 12.8 |

[1]By methods outlined in T. W. Lambe's *Soil Testing for Engineers,* John Wiley and Sons, New York, New York, 1951.

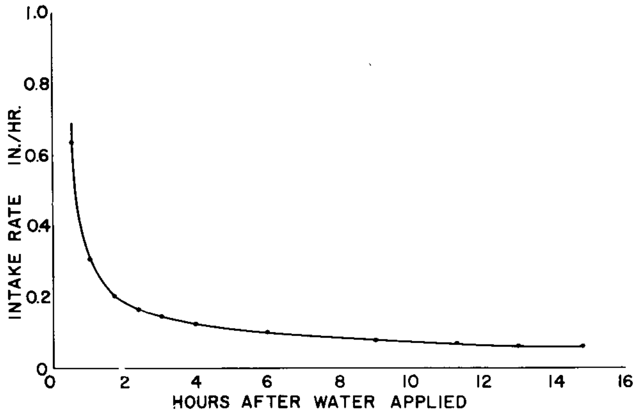


**Figure 7. Water intake rate on Pullman silty clay loam in relation to duration of application.**

## *Management Problems with Pullman Soils*

Effective moisture conservation and efficient utilization of moisture are major soil management problems under dryland farming conditions in the hardlands area of the High Plains. Crop yields usually are determined by available moisture supply. When moisture is adequate, a high yield potential exists. When available moisture supply is low, crop yields are low. Terracing, contour farming, conservation benching, summer fallowing and skip-row planting are methods of conserving or more effectively utilizing rainfall. In addition, weed control, including control of volunteer crops, is important in moisture conser-

TABLE 9. CHARACTERISTICS OF ROSCOE CLAY[1] AT THE SOUTHWESTERN GREAT PLAINS FIELD STATION[2], BUSHLAND, TEXAS

| Depth | Sand[3] | Silt[3] | Clay[3] | Texture | pH[4] | Organic matter[5] | Wilting[6] | Nitrogen[7] |
|---|---|---|---|---|---|---|---|---|
| Inches | — — Percent — — | | | | | — — Percent — — | | |
| 0- 2 | 27.2 | 32.5 | 40.3 | clay | 7.5 | 3.34 | 14.2 | 0.13 |
| 2- 5 | 29.2 | 28.0 | 42.8 | clay | 7.3 | 2.62 | 15.9 | 0.10 |
| 5-13 | 28.0 | 28.2 | 43.8 | clay | 8.1 | 1.36 | 17.3 | 0.08 |
| 13-25 | 27.6 | 27.2 | 45.2 | clay | 8.3 | 0.89 | 17.2 | 0.05 |
| 25-37 | 28.4 | 26.4 | 45.2 | clay | 8.5 | 0.62 | 15.8 | 0.05 |
| 37-55 | 28.8 | 29.8 | 41.4 | clay | 8.5 | 0.58 | 14.8 | 0.03 |
| 55-64 | 56.5 | 20.3 | 23.2 | sandy clay loam | 8.7 | 0.05 | 7.7 | 0.01 |
| 64-78 | 55.8 | 21.6 | 22.6 | sandy clay loam | 8.8 | 0.06 | 6.0 | 0.01 |
| 78-82 | 35.8 | 32.0 | 32.2 | clay | 8.5 | 0.13 | 11.4 | 0.01 |

[1]Unpublished data L. K. Eby.
[2]Sample location: 2400 feet north and 1386 feet west of southeast corner of west ½ Section 178, Block 9, BS&F Survey.
[3]Hydrometer.
[4]Glass electrode.
[5]Wet combustion.
[6]Sunflower method.
[7]Kjeldahl.

TABLE 7. SOIL MOISTURE RETENTION AND BULK DENSITY DATA FOR CULTIVATED PULLMAN SILTY CLAY LOAM

| Soil depth | Atmospheres soil moisture tension | | | | Bulk density[3] |
|---|---|---|---|---|---|
| | 1/3[1] | 1[1] | 5[2] | 15[2] | |
| Inches | — — — — — Percent — by weight | | | | G/cm[3] |
| 0- 5 | 28.3 | 19.2 | 13.8 | 11.1 | 1.39 |
| 5- 9 | 32.0 | 24.0 | 18.9 | 15.4 | 1.50 |
| 9-18 | 34.9 | 26.7 | 21.8 | 17.1 | 1.50 |
| 18-28 | 34.0 | 26.2 | 21.3 | 16.4 | 1.50 |
| 28-38 | 32.5 | 24.4 | 21.0 | 15.1 | 1.58 |
| 38-53 | 32.5 | 25.0 | 19.8 | 15.8 | 1.59 |
| 53-58 | 30.0 | 24.6 | 21.9 | 11.3 | 1.67 |
| 58-76 | 29.8 | | | | |
| 80-85 | 28.9 | 23.1 | 17.4 | 12.6 | |

[1]Pressure plate technique.

[2]Pressure membrane technique.

[3]Soil core with Pomona Sampler.

station and occurs in similar positions throughout the High Plains. Randall soils are gray clayey intrazonal soils (Grumusols) found in the Chestnut and Reddish Brown soil zones of the Southern Great Plains. They have developed on clays and silts of the High Plains sediments that have been modified by poor drainage. Randall clay soils remain under water for extended periods following rainy seasons. Because of flooding and undesirable physical properties, most Randall soils are unsuited for cultivation. However, some of the Randall soils located in shallow playas are cultivated. In deeper lakes, some Randall soils may be cultivated if special provision is made to intercept the runoff water usually flooding these soils during rainy seasons.

Zita, Potter and Portales soils occupy significant acreages in the fine-textured portion of the High Plains area, but they do not occur on the experiment station. These latter soils generally are more calcareous in the upper horizons than are Pullman soils.

TABLE 8. ATTERBERG LIMITS FOR PULLMAN SILTY CLAY LOAM

| Horizon | Liquid limit[1] | Plastic limit[1] | Plasticity index |
|---|---|---|---|
| Inches | — — Percent — — | | |
| 0- 5 | 30.5 | 20.4 | 10.1 |
| 5- 8 | 30.3 | 20.8 | 9.5 |
| 8-13 | 37.5 | 22.2 | 15.3 |
| 13-19 | 46.4 | 25.8 | 20.6 |
| 19-28 | 44.0 | 24.2 | 19.8 |
| 28-38 | 39.4 | 22.0 | 17.4 |
| 38-49 | 36.3 | 21.5 | 14.8 |
| 49-61 | 38.3 | 21.4 | 16.9 |
| 61-76 | 33.0 | 20.2 | 12.8 |

[1]By methods outlined in T. W. Lambe's *Soil Testing for Engineers,* John Wiley and Sons, New York, New York, 1951.

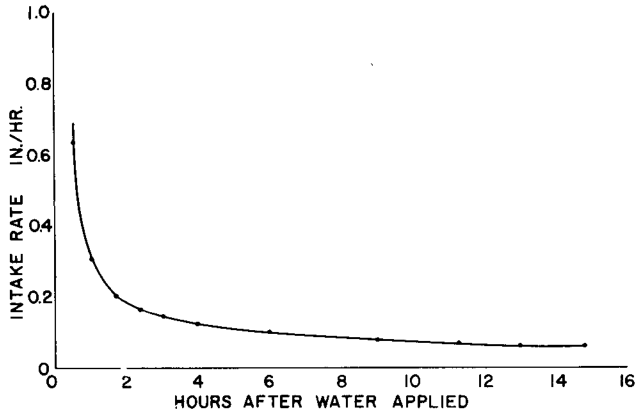


Figure 7. Water intake rate on Pullman silty clay loam in relation to duration of application.

# *Management Problems with Pullman Soils*

Effective moisture conservation and efficient utilization of moisture are major soil management problems under dryland farming conditions in the hardlands area of the High Plains. Crop yields usually are determined by available moisture supply. When moisture is adequate, a high yield potential exists. When available moisture supply is low, crop yields are low. Terracing, contour farming, conservation benching, summer fallowing and skip-row planting are methods of conserving or more effectively utilizing rainfall. In addition, weed control, including control of volunteer crops, is important in moisture conser-

TABLE 9. CHARACTERISTICS OF ROSCOE CLAY[1] AT THE SOUTHWESTERN GREAT PLAINS FIELD STATION[2], BUSHLAND, TEXAS

| Depth | Sand[3] | Silt[3] | Clay[3] | Texture | pH[4] | Organic matter[5] | Wilting[6] | Nitrogen[7] |
|---|---|---|---|---|---|---|---|---|
| Inches | — — Percent — — | | | | | — — Percent — — | | |
| 0- 2 | 27.2 | 32.5 | 40.3 | clay | 7.5 | 3.34 | 14.2 | 0.13 |
| 2- 5 | 29.2 | 28.0 | 42.8 | clay | 7.3 | 2.62 | 15.9 | 0.10 |
| 5-13 | 28.0 | 28.2 | 43.8 | clay | 8.1 | 1.36 | 17.3 | 0.08 |
| 13-25 | 27.6 | 27.2 | 45.2 | clay | 8.3 | 0.89 | 17.2 | 0.05 |
| 25-37 | 28.4 | 26.4 | 45.2 | clay | 8.5 | 0.62 | 15.8 | 0.05 |
| 37-55 | 28.8 | 29.8 | 41.4 | clay | 8.5 | 0.58 | 14.8 | 0.03 |
| 55-64 | 56.5 | 20.3 | 23.2 | sandy clay loam | 8.7 | 0.05 | 7.7 | 0.01 |
| 64-78 | 55.8 | 21.6 | 22.6 | sandy clay loam | 8.8 | 0.06 | 6.0 | 0.01 |
| 78-82 | 35.8 | 32.0 | 32.2 | clay | 8.5 | 0.13 | 11.4 | 0.01 |

[1]Unpublished data L. K. Eby.

[2]Sample location: 2400 feet north and 1386 feet west of southeast corner of west ½ Section 178, Block 9, BS&F Survey.

[3]Hydrometer.

[4]Glass electrode.

[5]Wet combustion.

[6]Sunflower method.

[7]Kjeldahl.

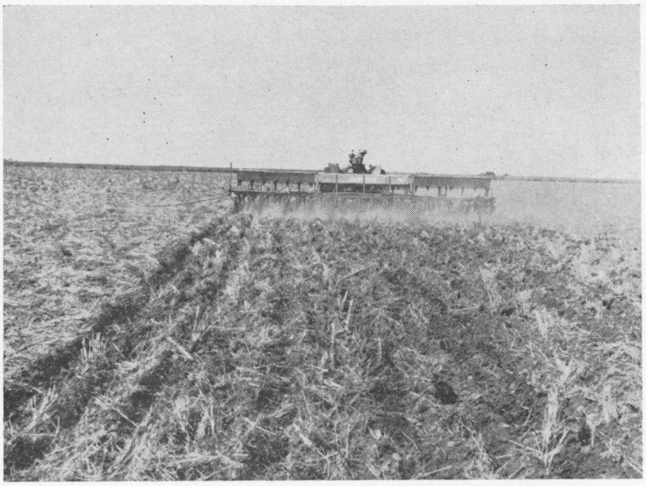

**Figure 8. Seeding wheat on stubble-mulched Pullman soil. Stubble mulching is an effective practice to reduce wind and water erosion on Pullman soils. (Photo courtesy Soil Conservation Service, U. S. Department of Agriculture).**

vation. Weedy crops use as much soil moisture as weed-free crops but produce less yield.

With irrigation, adequate moisture to control wind erosion can be supplied. Under dryland farming conditions, wind erosion can become severe on Pullman and associated soils during years of low rainfall. Stubble-mulch tillage, which leaves crop residue on the soil surface, and emergency tillage to produce a cloddy, rough soil surface usually will control wind erosion damage. Mansker, Portales and Drake soils are more erodible by wind than are Pullman soils. Usually Mansker, Portales and Drake soils occur on steeper slopes; they have lower inherent productivity; they are more calcareous. These factors combine to increase erodibility of these soils when compared to Pullman.

**TABLE 10. CHARACTERISTICS OF MANSKER CLAY LOAM[1] AT THE SOUTHWESTERN GREAT PLAINS FIELD STATION[2], BUSHLAND, TEXAS**

| Depth | Sand[3] | Silt[3] | Clay[3] | Texture | pH[4] | Organic matter[5] | Wilting[6] | Nitrogen[7] |
|---|---|---|---|---|---|---|---|---|
| Inches | — — Percent | — — | | | | — — Percent | — — | |
| 0- 1 | 36.4 | 45.4 | 18.2 | loam | 8.0 | 2.31 | 10.9 | 0.22 |
| 1- 5 | 33.4 | 32.4 | 34.2 | clay loam | 7.9 | 3.17 | 10.9 | 0.16 |
| 5-13 | 29.4 | 26.4 | 44.2 | clay | 8.1 | 1.56 | 11.1 | 0.09 |
| 13-30 | 31.8 | 33.0 | 35.2 | clay loam | 8.1 | 1.99 | 10.3 | 0.04 |
| 30-48 | 37.6 | 28.0 | 34.4 | clay loam | 8.3 | 1.61 | 10.5 | 0.03 |
| 48-74 | 30.2 | 28.2 | 41.6 | clay | 8.2 | 0.23 | 11.0 | 0.02 |

[1]Unpublished data L. K. Eby.
[2]Sample location: west 890 feet, south 470 feet from northeast corner of pasture, Section 197, Block 9, BS&F Survey.
[3]Hydrometer.
[4]Glass electrode.
[5]Wet combustion.
[6]Sunflower method.
[7]Kjeldahl.

The low water intake rate is a characteristic of Pullman soils. Figure 7 illustrates water intake rate of Pullman silty clay loam as it varies with time. Initially, water intake rate is appreciable while cracks and other temporary storage volumes in the soil are filled with water. At the end of 10 hours, however, intake rates are about 0.05 to 0.10 inch per hour. This extremely low residual intake rate is a critical factor in irrigation and terrace system designs. A 3-inch irrigation usually will soak into Pullman silty clay loam in 6 hours or less, but the last 3 inches of an 8-inch irrigation may require as long as 3 days to penetrate Pullman soil. For this reason, it is sometimes necessary to apply a smaller amount of irrigation water than is really desirable from an irrigation efficiency standpoint. Especially during midsummer, water standing too long on the soil surface can cause poor soil aeration and subsequently cause crops to "drown."

**TABLE 11. FERTILITY STATUS OF DRYLAND CULTIVATED PULLMAN SILTY CLAY LOAM[1]**

| Depth | Total nitrogen | Extractable $P_2O_5$[2] | Extractable potassium[3] | Acid extractable zinc[4] |
|---|---|---|---|---|
| Inches | Percent | — — — — | PPM | — — — — |
| 0- 5 | .106 | 47 | 475 | 3.3 |
| 5- 8 | .105 | 9 | 440 | 1.3 |
| 8-13 | .082 | 5 | 425 | 1.0 |
| 13-19 | .062 | 3 | 450 | 0.8 |
| 19-28 | .053 | 5 | 475 | 0.6 |
| 28-38 | .049 | 9 | 425 | 0.5 |
| 38-56 | .035 | 7 | 420 | 1.1 |
| 56-65 | .021 | 3 | 210 | 0 |

[1]Unpublished data of H. V. Eck.
[2]Sodium bicarbonate soluble.
[3]Normal neutral ammonium acetate.
[4]Soluble in 0.1N Hcl.

Aeration problems may also develop in Pullman soils even when the soil is not under water. Low internal drainage rates, high bulk densities and high amounts of moisture retained at field capacity combine to produce conditions of poor soil aeration when a Pullman soil is at or near field capacity. If substantial rains follow a large irrigation, susceptible crops, such as tomatoes and alfalfa are likely to be severely damaged. Wheat and grain sorghum are more tolerant of poor aeration conditions.

Tillage operations conducted too soon after rainfall or an irrigation result in puddling or compacting of the soil. This adverse condition can be reduced by carefully timed tillage operations. Unless soil structure is severely damaged, Pullman soils will regenerate favorable soil structure through natural mechanisms such as alternate freezing-thawing or wetting-drying. Occasionally, tillage deep enough to shatter a plowpan will be required to speed development of a desirable soil structure.

**Figure 9. Plant nutrient deficiencies are a major factor limiting crop yields on irrigated Pullman soils. Both plots in the photograph received a preplant irrigation and three irrigations after planting. Two hundred and forty pounds of nitrogen were applied on the plot on the left. It produced 7,820 pounds per acre of grain sorghum; the plot on the right received no nitrogen and produced 2,980 pounds. (Photo courtesy M. E. Jensen and W. H. Sletten.)**

Contents of nitrogen, extractable phosphorus, extractable potassium and acid extractable zinc in a dryland cultivated Pullman silty clay loam are presented in Table 11. Field and greenhouse experiments have shown that this soil contains adequate plant nutrient elements for maximum yields under dry farming, but it responds to nitrogen fertilization under irrigated conditions. Contents of other elements are adequate for maximum yields under both dryland and irrigation farming conditions.

If the surface soil is removed (by land forming, erosion and such), the soil responds to both phosphorus and nitrogen fertilization. Critical levels of zinc have not been established for this soil, but the low acid extractable zinc level in the subsoil indicates that it may be deficient for zinc-sensitive crops when the topsoil is removed.

## *Acknowledgments*

A preliminary soil survey of the Southwestern Great Plains Field Station was made by Claude L. Fly, Soil Conservation Service, U. S. Department of Agriculture, in the fall of 1937. The field station was resurveyed by M. W. Howard, Soil Conservation Service, USDA, September 1944, and by E. H. Templin, Soil Conservation Service, USDA, April 1951. A recommended correlation of the soils was made by R. E. Daniell and L. C. Geiger, Soil Conservation Service, USDA, December 1961. J. R. Coover, state soil scientist, Soil Conservation Service, USDA, recommended amendments to this correlation October 19, 1962. The final correlation was made by R. M. Simonson, Soil Conservation Service, USDA, January 21, 1963.

Appreciation is expressed to the present and former staff members of the Southwestern Great Plains Field Station, whose research made this publication possible.

This research was conducted jointly by the Soil and Water Conservation Research Division, Agricultural Research Service, USDA; the Texas Agricultural Experiment Station; and the Soil Conservation Service, USDA.

Cover photograph courtesy of L. L. Jacquot, Soil Conservation Service, USDA.

## *Bibliography*

A list of publications relating to soil and crop management on the Pullman and other hardland soils of the Southern Great Plains follows.

Army, T. J., J. J. Bond and C. E. Van Doren. Precipitation-yield relationship in dryland wheat production on medium to fine-textured soils of the Southern High Plains. Agron. Journ. 51 (12) : 721-724. 1959.

Army, T. J. and E. B. Hudspeth, Jr. Better grass establishment with plastic covers. Texas Agr. Progress 5 (4) : 20, 22-23. 1959.

Army, T. J. and E. B. Hudspeth, Jr. Alteration of the micro-environment of the seed zone. Agron. Journ. 52: 17-22. 1960.

Atkins, I. M., J. H. Gardenhire and K. B. Porter. Barley production in Texas. Tex. Agr. Expt. Sta. Bull. 918. 1958.

Atkins, I. M., J. H. Gardenhire and K. B. Porter. Oats for grain, winter pasture and other uses. Tex. Agr. Expt. Sta. Bull. 929. 1959.

Atkins, I. M., K. B. Porter, K. Lahr, O. G. Merkle and M. C. Futrell. Wheat production in Texas. Tex. Agr. Expt. Sta. Bull. 948. 1960.

Bond, J. J. and T. J. Army. Dryland wheat farming on the Southern Great Plains. Soil Conservation 24 (12). 1959.

Bond, J. J., T. J. Army, O. R. Lehman and J. F. Cherry. Narrow-row sorghum for the hardlands of the High Plains. Tex. Agr. Expt. Sta. Progress Report 2019. 1958.

Bond, J. J. and T. J. Army. Keep the stubble on the surface. Soil and Water 7 (10) : 12. 1958.

Bond, J. J., C. E. Van Doren and T. J. Army. Fallowing for wheat production. Journ. of Soil and Water Conservation 16 (4) : 163-165. 1961.

Coover, J. R., C. E. Van Doren and C. J. Whitfield. Some characteristics of the Pullman soils on the Amarillo Experiment Station. Tex. Agr. Expt. Sta. Misc. Pub. 97. 1953.

Daniels, N. E. Protecting young grain sorghum from soil insects. Tex. Agr. Expt. Sta. Progress Report 2172. 1961.

Daniels, N. E. Chemical control of a species of the false chinch bug group in grain sorghum. Tex. Agr. Expt. Sta. Progress Report 2063. 1958.

Daniels, N. E. Greenbug populations in winter wheat as affected by grazing. Tex. Agr. Expt. Sta. Progress Report 2000. 1957.

Daniels, N. E. Greenbug populations and their damage to winter wheat as affected by fertilizer applications. Journ. Econ. Ent. 50: 793-794. 1957.

Daniels, N. E. Evidence of the oversummering of the greenbug in the Texas Panhandle. Journ. Econ. Ent. 53: 454-455. 1960.

Daniels, N. E. Greenbug control with systemic insecticides as influenced by fertilizer applications. Journ. Econ. Ent. 53: 278-279. 1960.

**Figure 9. Plant nutrient deficiencies are a major factor limiting crop yields on irrigated Pullman soils. Both plots in the photograph received a preplant irrigation and three irrigations after planting. Two hundred and forty pounds of nitrogen were applied on the plot on the left. It produced 7,820 pounds per acre of grain sorghum; the plot on the right received no nitrogen and produced 2,980 pounds. (Photo courtesy M. E. Jensen and W. H. Sletten.)**

Contents of nitrogen, extractable phosphorus, extractable potassium and acid extractable zinc in a dryland cultivated Pullman silty clay loam are presented in Table 11. Field and greenhouse experiments have shown that this soil contains adequate plant nutrient elements for maximum yields under dry farming, but it responds to nitrogen fertilization under irrigated conditions. Contents of other elements are adequate for maximum yields under both dryland and irrigation farming conditions.

If the surface soil is removed (by land forming, erosion and such), the soil responds to both phosphorus and nitrogen fertilization. Critical levels of zinc have not been established for this soil, but the low acid extractable zinc level in the subsoil indicates that it may be deficient for zinc-sensitive crops when the topsoil is removed.

## *Acknowledgments*

A preliminary soil survey of the Southwestern Great Plains Field Station was made by Claude L. Fly, Soil Conservation Service, U. S. Department of Agriculture, in the fall of 1937. The field station was resurveyed by M. W. Howard, Soil Conservation Service, USDA, September 1944, and by E. H. Templin, Soil Conservation Service, USDA, April 1951. A recommended correlation of the soils was made by R. E. Daniell and L. C. Geiger, Soil Conservation Service, USDA, December 1961. J. R. Coover, state soil scientist, Soil Conservation Service, USDA, recommended amendments to this correlation October 19, 1962. The final correlation was made by R. M. Simonson, Soil Conservation Service, USDA, January 21, 1963.

Appreciation is expressed to the present and former staff members of the Southwestern Great Plains Field Station, whose research made this publication possible.

This research was conducted jointly by the Soil and Water Conservation Research Division, Agricultural Research Service, USDA; the Texas Agricultural Experiment Station; and the Soil Conservation Service, USDA.

Cover photograph courtesy of L. L. Jacquot, Soil Conservation Service, USDA.

## *Bibliography*

A list of publications relating to soil and crop management on the Pullman and other hardland soils of the Southern Great Plains follows.

Army, T. J., J. J. Bond and C. E. Van Doren. Precipitation-yield relationship in dryland wheat production on medium to fine-textured soils of the Southern High Plains. Agron. Journ. 51 (12) : 721-724. 1959.

Army, T. J. and E. B. Hudspeth, Jr. Better grass establishment with plastic covers. Texas Agr. Progress 5 (4) : 20, 22-23. 1959.

Army, T. J. and E. B. Hudspeth, Jr. Alteration of the microenvironment of the seed zone. Agron. Journ. 52: 17-22. 1960.

Atkins, I. M., J. H. Gardenhire and K. B. Porter. Barley production in Texas. Tex. Agr. Expt. Sta. Bull. 918. 1958.

Atkins, I. M., J. H. Gardenhire and K. B. Porter. Oats for grain, winter pasture and other uses. Tex. Agr. Expt. Sta. Bull. 929. 1959.

Atkins, I. M., K. B. Porter, K. Lahr, O. G. Merkle and M. C. Futrell. Wheat production in Texas. Tex. Agr. Expt. Sta. Bull. 948. 1960.

Bond, J. J. and T. J. Army. Dryland wheat farming on the Southern Great Plains. Soil Conservation 24 (12). 1959.

Bond, J. J., T. J. Army, O. R. Lehman and J. F. Cherry. Narrow-row sorghum for the hardlands of the High Plains. Tex. Agr. Expt. Sta. Progress Report 2019. 1958.

Bond, J. J. and T. J. Army. Keep the stubble on the surface. Soil and Water 7 (10) : 12. 1958.

Bond, J. J., C. E. Van Doren and T. J. Army. Fallowing for wheat production. Journ. of Soil and Water Conservation 16 (4) : 163-165. 1961.

Coover, J. R., C. E. Van Doren and C. J. Whitfield. Some characteristics of the Pullman soils on the Amarillo Experiment Station. Tex. Agr. Expt. Sta. Misc. Pub. 97. 1953.

Daniels, N. E. Protecting young grain sorghum from soil insects. Tex. Agr. Expt. Sta. Progress Report 2172. 1961.

Daniels, N. E. Chemical control of a species of the false chinch bug group in grain sorghum. Tex. Agr. Expt. Sta. Progress Report 2063. 1958.

Daniels, N. E. Greenbug populations in winter wheat as affected by grazing. Tex. Agr. Expt. Sta. Progress Report 2000. 1957.

Daniels, N. E. Greenbug populations and their damage to winter wheat as affected by fertilizer applications. Journ. Econ. Ent. 50: 793-794. 1957.

Daniels, N. E. Evidence of the oversummering of the greenbug in the Texas Panhandle. Journ. Econ. Ent. 53: 454-455. 1960.

Daniels, N. E. Greenbug control with systemic insecticides as influenced by fertilizer applications. Journ. Econ. Ent. 53: 278-279. 1960.

Eck, H. V. and C. Fanning. Fertilization of dryland winter wheat under stubble mulch and one way tillage on Pullman silty clay loam. Tex. Agr. Expt. Sta. Misc. Pub. 584, 1962.

Ellis, G. F., O. R. Lehman and J. J. Bond. Effect of nitrogen fertilizer on yield and composition of irrigated sudangrass on the High Plains. Tex. Agr. Expt. Sta. Progress Report 2173. 1961.

Finnell, H. H. Moisture storage and crop yields in the dry-farming areas of the Great Plains. USDA Production Research Report 39. 1960.

Hauser, V. L. New conservation tool: Bench terraces. Soil and Water 11 (11:13). 1961.

Hauser, V. L. What's new in terraces? Bench terrace yields. Soil and Water 11 (6) 7-8. 1961.

Hauser, V. L. and R. R. Allen. Runoff measured on silty clay loam soils on the High Plains of Texas. Tex. Agr. Expt. Sta. Progress Report 2098. 1959.

Hauser, V. L. and A. W. Zingg. Conservation benching. Soil and Water 8 (1) :12. 1959.

Hudspeth, E. B., Jr. and G. F. Ellis. Effect of soil moisture on the emergence of Blackwell switchgrass. Tex. Agr. Expt. Sta. Progress Report 2085. 1959.

Hudspeth, E. B., Jr. and H. M. Taylor. Improving grass stands on the Southern Great Plains. Agr. Research 10 (3) :5. September 1961.

Hudspeth, E. B., Jr. and H. M. Taylor. Factors affecting seedling emergence of Blackwell switchgrass. Agron. Journ. 53 (5) : 331-335. 1961.

Jensen, M. E. and W. Clyma. What happens to sediments in playa lake water when used for underground recharge in wells? Cross Section 5 (8) : 2-3. 1959.

Jensen, M. E. and W. H. Sletten. Good irrigation management brings increased sorghum yields. Soil and Water 6: 7,8-9. 1957.

Jensen, M. E. and W. H. Sletten. How much? How often? Irrigation questions that need answering. Soil and Water 7: 7, 12. 1958.

Johnson, W. C. Stubble mulch farming on wheatlands of the Southern High Plains. USDA Circ. 860. 1950.

King, J. G. and J. W. Collier. Performance of grain sorghum hybrids and varieties, High Plains and Pecos area, 1957-1960. Tex. Agr. Expt. Sta. Progress Report 2182. 1961.

Lotspeich, F. B. and J. R. Coover. Soil forming factors on the Llano Estacado. I. Parent material, time, and topography. Tex. Journ. of Sci. XIV (1) : 7-17. 1962.

Lotspeich, F. B., and M. E. Everhart. Climate and vegetation as soil forming factors on the Llano Estacado. Journ. of Range Management. 15:134-141. 1962.

Mathers, A. C., F. G. Viets, M. E. Jensen and W. H. Sletten. Relationships of nitrogen and grain sorghum yield under three moisture regimes. Agron. Journ. 52 (8) : 443-446. 1960.

Pope, A. Fertilizer trials on irrigated grain sorghum at five locations, High Plains, 1957. Tex. Agr. Expt. Sta. Progress Report 2033. 1958.

Pope, A. Fertilizer trials on irrigated winter wheat at seven locations, High Plains, 1957. Tex. Agr. Expt. Sta. Progress Report 2034. 1958.

Pope, A. Effect of application schedule and source of phosphorus fertilizer on forage yield, phosphorus content and protein content of 12 cuttings of irrigated alfalfa. Tex. Agr. Expt. Sta. Progress Report 2214. 1961.

Porter, K. B., M. E. Jensen and W. H. Sletten. The effect of row spacing, fertilizer and planting rate on the yield and water use of irrigated grain sorghum. Agron. Journ. 52: 431-434. 1960.

Swanson, N. P. and E. L. Thaxton, Jr. Requirements for grain sorghum irrigation on the High Plains. Tex. Agr. Expt. Sta. Bull. 846. 1957.

Taylor, H. M. Moisture relationships of some rangeland soils of the Southern Great Plains. Journ. of Range Management 13 (2) : 77-80. 1960.

Wiese, A. F. and T. J. Army. Effect of chemical fallow on soil moisture storage. Agron. Journ. 52: 612-613. 1960.

Wiese, A. F., J. J. Bond and T. J. Army. Chemical fallow in the Southern Great Plains. Weeds 8:284-290. 1960.

Wiese, A. F. and E. B. Hudspeth, Jr. Effect of weed control practices on the establishment of Vaughn side-oats grama (*Bouteloua curtipendula*). Proc. North Central Weed Conference. 1960.

Wiese, A. F. and H. E. Rea. Bindweed (*Convolvolus arvensis L*) control and seedling emergence as affected by tillage, 2,4-D and competitive crops. Agron. Journ. 51: 672-675. 1959.

Wiese, A. F. and H. E. Rea. Bindweed control. Tex. Agr. Progress 5 (3) : 5-6. 1959.

Wiese, A. F. and H. E. Rea. Weed control on Northwest Texas cropland. Tex. Agr. Progress 7 (4) : 5-7. 1961.

Wiese, A. F. and H. E. Rea. Control of field bindweed and other perennial weeds with Benzoic and phenylacitic acids. Weeds 9:423-428. 1961.

Whitfield, C. J., C. E. Van Doren and W. C. Jonhson. Stubble mulch management for water conservation and erosion control on hardlands of the Southern Great Plains. Tex. Agr. Expt. Sta. Bull. 711. 1949.